SUGGESTIONS FOR INSPECTION OF ROOF-BOLT INSTALLATIONS

By Edward Thomas

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INTRODUCTION

In 1947 the Bureau of Mines, as an accident-prevention measure, decided to advocate the adoption of roof bolting (suspension roof supports) in coal mines where it appeared to be applicable. Subsequent experience has disclosed that the applicability of this support is more general than was first suspected; moreover, comparison of the accident records of mines before and after adoption of the roof-bolting method shows results that more than justify the effort and funds expended. The industry has responded enthusiastically, because roof bolting proved to be not only an accident-prevention measure but also one to increase productive efficiency. In some instances this increase in the productivity of men and machines has been almost incredible and has led many mining men to conclude that through some hocus-pocus they can now cast aside many or all of the time-proven rules of good mining practice. If this tendency is not counteracted, it could easily result in an increase of roof-fall accidents, which may outweigh the benefits of roof bolting and discredit an innovation in roof control that shows great promise of materially reducing our mining accidents. From an economic standpoint it may represent the margin between profit and loss in many mining operations.

The purpose of this manuscript is not to propose an inflexible code or set of rules but to summarize the experience to date as a guide for those who have the responsibility for the installation and inspection of roof bolts. This experience consists of approximately 250 investigations of roof failure in which roof bolting was involved either directly or indirectly. It should be pointed out that many of these failures were controlled, occurring during experimental periods, and comparatively few of the accidental failures actually resulted in personal injury, yet a significant number represented potential hazards.

PROCEDURES IN ADOPTING ROOF BOLTING

Roof bolting is practices in over 450 coal mines and 50 noncoal mines in the United States; yet the experience that has been gained has not made it possible to draft a set of general rules that would enable a particular mine to adopt roof bolting with any degree of assurance that the rules would fit the circumstances likely to be encountered. This, of course, is the objective that we should strive to attain through research. However, because of the variables encountered in different mines, mining methods, and the heterogeneity of roof rocks, it appears impracticable, if not impossible, in the near future. The problem is complicated by our lack of practical means of predicting the resultant changes in roof-stress distribution that follow these variations.

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Recognizing these factors, it has been the policy of the Bureau of Mines not to sponsor or condone the adoption of roof-bolting practice in any mine unless it is preceded by one or more experimental installations in which bolting is supplemented by the same amount of conventional timbering formerly used. Ordinarily, these experimental installations are made in roadways where men do not travel regularly after completion, so that the supplementing timbers can be removed without introducing a hazard to passersby, and the effectiveness of the bolts can be observed over a period of several months. By varying the patterns, the type of bolts, and the method of installation, enough experience is obtained usually, without undue delay or expense, to arrive at a scheme that affords a good factor of safety and maximum of efficiency. This experimental period also serves to acquaint the workmen with the unfamiliar tools required and enables them under supervision to become expert in installing the bolts properly.

ROOF FALLS IN BOLTED AREAS

As stated above, our knowledge of the mechanics of transmittal of stress through bedded strata is limited; nevertheless, the following principle has not been disputed: The effect of roof bolts, insofar as the immediate roof is concerned and considering it as a simple beam, is to bind or tie together thin, weak strata that otherwise would separate and act as independent beams. This consolidation of the strata increases the thickness of the beam across the opening. Thus, it is logical that the most important factors that could contribute to a failure of bolted roof are:

1. Installation of an insufficient number of bolts or installation in such a way that the resultant beam is not consolidated.

Experience shows that 90 percent of the roof falls investigated are in this category. These failures resulted from not having or not carrying out a predetermined plan and from depending on the judgment of individuals in placing the bolts. In other words, the underlying cause of most roof-fall accidents remains the same as it has been from the time underground mining first began - failure to provide adequate support at the proper time. The remedy is also the same - a methodical minimum plan for installing supports and proper supervision to enforce the plan.

The basic difference between bolting the roof and supporting it with timbers is that timbers offer support after the strata that they are supporting have failed, whereas roof bolts reinforce the roof rock and it contributes to its own support. A roof beam composed of a series of failed strata reinforced with steel rods obviously cannot be depended on. Therefore, to take full advantage of bolting, the bolts should be installed promptly as the face advances and before the immediate roof has had an opportunity to sag appreciably.

This does not mean that the roof should never be bolted outby the immediate face area. Such bolting is feasible in three situations: 1. Where enough bolts were installed as the face advanced but later a room or crosscut opening was made. Additional bolts should be installed before such cut is made. 2. Where it is necessary to brush the bolted top by blasting the immediate roof. If the bolts were holding properly before the blasting, there is no reason why the new immediate roof can not be bolted if the bolts are properly anchored and if the work is done promptly. However, the bolts should not be

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loosened before blasting unless jacks or timbers are placed for the protection of the worker, and drilling and installing of new bolts should not be done without the protection of safety posts and jacks. 3. Where broken timbers must be replaced and loose roof supported, if anchorage can be obtained for a distance of at least 12 inches in a stratum that has not or is not likely to be not flexed excessively. This should never be attempted without an experimental period, and under ordinary circumstances it should be discouraged.

There are several types of anchoring devices on the market, and the relative effectiveness of the various makes is controversial. Each has its particular advantages and limitations, and the Bureau of Mines does not discriminate between them; therefore, the individual bolt must be examined without prejudice to determine whether or not it is doing the task for which it was designed. The ideal bolt should be do designed and installed that its anchor will not slip when the bolt is loaded to its yield-point capacity, and it should have enough bearing area, either as frictional area along the rod itself or at a bearing plate. Some miners believe that if they are able to anchor bolts into a massive stratum they are utilizing the entire strength of this stratum as a beam, and they attempt to widen openings beyond safe limits. Experience shows that regardless of the natural planes of weakness in the stratification, an artificial plane of weakness is induced in the rock that is parallel to the bedding planes, and it passes through the points corresponding to the bolt ends having the deepest penetration. With the anchoring devices in use, enormous amounts of shear and compressive forces must be exerted to anchor the bolt properly, and this induces a plane of weakness in the same manner that planes of weakness are created in quarrying rock by the wedge-and-feather method. Staggering the lengths of the bolts does not eliminate this factor; it only weakens the structure of the available beam. Therefore, the safety of the span that can be bridged depends on the length of the bolts used and the penetration obtained.

GUIDE FOR INSPECTORS

General

The inspector should examine the mine plans before making inspections. If bolting is being done and no bolting plan has been made, he should contact a roof-control specialist at once. New installations should be considered experimental and, ordinarily, should be installed according to the recommendations of experienced roof-control men.

Inspection

(a) Check the roof conditions in the face against the description of the conditions prevailing at the time a roof-control specialist's recommendations were made.

(b) Check the bolting pattern against the plan:

1. Average centers
2. Width of openings
3. Extra bolts at intersections and other wide spaces

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4. Bolt length and diameters

5. Plate dimensions

Installation of Bolts

(a) Use of safety jacks.

The same standard applies to safety posts or jacks when used with roof bolting as with conventional timbering: A man should never be permitted to work under unsupported roof at the face. In mechanical loading, safety posts should be set before a pickman or other worker advances beyond the last row of bolts. A safety post or jack should be set before a bolt is removed, and if additional bolts outby the face are needed, safety posts or jacks should be set for protection of the drillers.

(b) Proper anchoring of bolts.

Use of the slit-rod-and-wedge bolts and some types of expansion shells requires that the holes be drilled to a uniform depth, and this can be done to a tolerance of plus or minus 1 inch with a reasonable amount of supervision. If the hole is too deep, the bolt cannot be anchored properly, because the wedge or expansion shell does not seat against the back of the hole. If the hole drilled is too shallow, the end of the bolt will protrude too far our of the hole, and the maximum penetration of the bolt will not be utilized.

(c) Proper tools and procedure.

Two steps should be taken in installing the slit-rod-and-wedge bolt properly; first, the bolt should be seated by use of the device that has given the best results during the experimental test period; and second, the bearing plate should be tightened. This same procedure applies to most expansion shells. Attempts have been made to combine these steps into one operation, but experience has proved that it cannot be done effectively. By using some types of expansion shells the two operations can be combined safely; however, the practice in a few mines of drilling all holes in a face and anchoring the bolts before the bearing plates are fastened should not be permitted.

Power wrenches should be used for tightening the bearing-plate nuts, not only because of greater efficiency but because they tighten the bolts to a uniform tension, which is desirable to equalize the load. Torquometers should be used by foremen to test the torque settings of the power wrenches and the installation performance of the bolting crews.

Effectiveness of Installation

(a) Visual test.

The ultimate purpose of roof supports of any type is to support the mine roof in the areas where men are working or are likely to work or travel. If this is not done, a hazard exists. Inasmuch as most of the effective part of the bolt is hidden from the inspector's view, faulty supports cannot be detected as readily where roof bolts are used as where conventional timbering

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is used. Nevertheless, there are certain signs that will indicate faulty or overloaded bolts. Some of these taken alone are not enough justification for condemning an installation; however, all are worthy of the attention of the mine official responsible and of the roof-control specialist. Some of these danger signs are:

1. Sagging of the immediate roof, bowing appearance of cracks, particularly parallel to the ribs, or sloughing of immediate roof.

2. Effectiveness of bearing plates. Steel plates of insufficient thickness will cup and provide inadequate bearing and promote sloughing of the immediate roof. Wooden bearing plates (headers) provide a maximum of bearing surface and are often effective in preventing surface sloughing, however, they should be used only in rooms or other openings having short life. Because of its susceptibility to rot, wood does not make a good permanent bearing plate from the standpoint of retaining tension in the bolt.

3. Channels and angle washers. If channels are used they should be bent to conform to the irregularities of the roof, especially in the immediate vicinity of the bolts. Wooden blocking should not be used to secure the channel against the roof after the nut is tight against the channel. Angle washers should be strong enough to resist permanent deformation when the bolts are tightened

4. Protrusion of bolt ends. When a large percentage of the bolt ends of slit-rod-and-wedge-type bolts protrude beyond the nut to the extent that all of the available thread on the bolt is used, it is an indication that the holes were not drilled to the proper depth. This may result also when the bolts are not driven over the wedge enough and are not properly seated. When the impact wrench was applied, not enough resistance was exerted to stall the wrench until all the thread was used and it encountered the resistance of the rotation of the entire bolt. Uniformity of protrusion of bolt ends should also be viewed with suspicion, especially if the nuts are being tightened with hand wrenches. In low coal, where protruding bolt ends present a hazard, the protruding bolt end should be cut and/or rubber shields used.

(b) Mechanical tests.

The roof-testing rod is of little use in testing bolted areas. In some localities relative loading of bolts can be determined by tapping the heads of the bolts with a ball-peen hammer; but this test is not reliable in all strata. At present, the most practical instrument available for testing the effectiveness of bolts is the torquometer, which, through measurement of the torque applied at the nut, can approximate the bolt tension. Most companies using roof bolts equip their foremen with torquometers, and each Bureau roof-control man is so equipped.

Recovery of Bolts

The rule for the removal of conventional timbers applies also to the removal of bolts. A bolt should not be removed unless an equal amount of support is provided during the process of removal. The policy of the Bureau of Mines is to discourage the recovery of bolts unless it can be done in a manner that provides complete protection for the worker.

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INTERPRETATIONS OF STATE LAWS AND THE FEDERAL MINE SAFETY CODE REGARDING ROOF BOLTING

In the over-all picture, especially in coal mines, roof bolting has passed the experimental stage and has proved its effectiveness in preventing roof-fall accidents. It is therefore the policy of the Bureau of Mines to consider roof bolting as a means of roof support and to consider the words "roof bolts" or "roof bolting" to be interchangeable with the words "timber" or "timbering" in Article III of the Federal Mine Safety Code. Most State departments of mines also place roof bolting in a similar status, either by common consent or by rulings of the various attorneys general. In a few States, action is being taken to amend the mining laws to permit a similar interpretation.

Interior - Bureau of Mines, Pittsburgh, Pa.

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